CHAPTER 2
FUNDAMENTALS OF LIMITED VULNERABILITY DESIGN

2-1. Background

The current approach in combating terrorist attacks on government and private-sector structures has focused primarily on prevention and secondarily on construction. The primary reason for this approach is time considerations. Incorporating minor alterations in a building and security policies is much easier and less costly than completely replacing a structure, and the improvements are immediate. Programs and training initiatives that focus on Anti-terrorism/Force Protection (AT/FP) reflecting this approach are offered by both government and private-sector organizations.

a. Further, existing construction-based approaches to threat resistance are concentrated on external threats and consequently emphasize physical security and perimeter defense measures. Many C4ISR installations incorporate such measures, including CBR filtration of heating, ventilation, and air-conditioning (HVAC) system air intakes and blast-resistant louvers or barriers protecting exhaust air outlets for standby generators.

b. These types of measures, while necessary, have no effect against a threat delivered inside the secured perimeter by an individual who has penetrated security or may even be authorized to be in the space. The intent of the LVD concept, described below, is to redefine the approach to C4ISR facility and utility system construction to permit sustained mission operation following the delivery of such an internal threat.

2-2. Limitations of current practice

Current practice in the design of utility systems for C4ISR facilities incorporates reliability and maintainability considerations but with an emphasis on analyzing the configuration of systems against specified numerical reliability or availability criteria (see paragraph 2-7, Reliability Criteria).

a. Although this analysis emphasizes inherent failures and maintenance downtime; it does not address failure due to external factors such as environment or terrorist threat. The result is typically systems with a high degree of redundancy but little physical segregation or hardening other than that provided at the facility perimeter by traditional security systems.

b. This practice can be contrasted with that of the nuclear industry, where both reliability and security are considered in the design of critical systems. Well-known incidents such as the fire in the cable spreading room at the Browns Ferry plant and the partial uncovering of the reactor core at Three Mile Island Unit 2 have demonstrated the need for both redundant systems and redundant pathways, even for events involving only inherent failures. When the possibility of an intentionally hostile action within the secured perimeter is added, the result is a clear need for a different approach to the design of C4ISR facility utility systems.

2-3. Limited vulnerability design concept

The LVD concept is used to describe a building structure designed to *detect* potential terrorist threats, *isolate* resulting damage, and promote *survival* of personnel affected by an event, while *propagating* continued parallel mission activity. The LVD concept relies on compartmentalizing the construction of the C4ISR facility into multiple zones, each of which is separated from the other zones by barriers adequate to withstand the range of potential threats.

a. This approach is used along with redundancy of mechanical and electrical systems to accomplish two objectives: The first is to limit the effect of an event to the compartment, or zone, in which it occurs, allowing continued mission operation in other zones. The other objective is to prevent an event in any zone of the building from interrupting utility service to the most critical mission, such as a central command center.

b. For example, if a biological agent were introduced into the HVAC system of a structure, sensing and controls capable of detecting the agent would operate the HVAC system to contain the agent within the zone of introduction. If an explosion were to occur within a zone and disable utility service equipment in that zone, the mission in other zones would be unaffected and sources in other zones would continue to provide uninterrupted service to the most critical space.

2-4. Design basis threat

The range of potential threats for application of the LVD concept encompasses generally any weapon or agent that can be hand-carried into the facility by an individual and deployed or released inside the secured perimeter; it also includes any damaging action that can be taken by an individual inside the facility, such as manually discharging a wet sprinkler system over computer equipment.

a. There are many different types of conventional threats such as the ones listed below as well as others not yet defined or developed:

(1) Firearm discharge

(2) Explosion

(3) Fire

(4) Flood

(5) Toxic gas or liquid (chemical)

(6) Infectious agent (biological)

(7) Ionizing radiation source (radiological)

(8) Electromagnetic fields

(9) Software intrusion

b. The design basis threat should be defined specifically for each facility based on a risk and vulnerability assessment that considers mission, geographic location, and other factors.

c. With respect to structural threats such as explosion and fire, this TM is not intended to quantitatively define the threat level or to provide guidance in the design of structures to resist specific threats. It is assumed that other applicable standards will be used to determine the design basis threat for a specific facility and that the structural features separating zones of the facility will be designed to withstand the threat according to those standards. This TM focuses on the design of the utility systems in unaffected zones to detect, respond to, and survive the threat.

2-5. Example C4ISR facility

Figures 2-1 and 2-2 present floor plans of an example C4ISR facility to illustrate the application of LVD concepts to the design of utility systems. This example is not intended to limit either the size or the mission character of potential facilities but simply to assist in explaining the application of design concepts discussed in this TM.

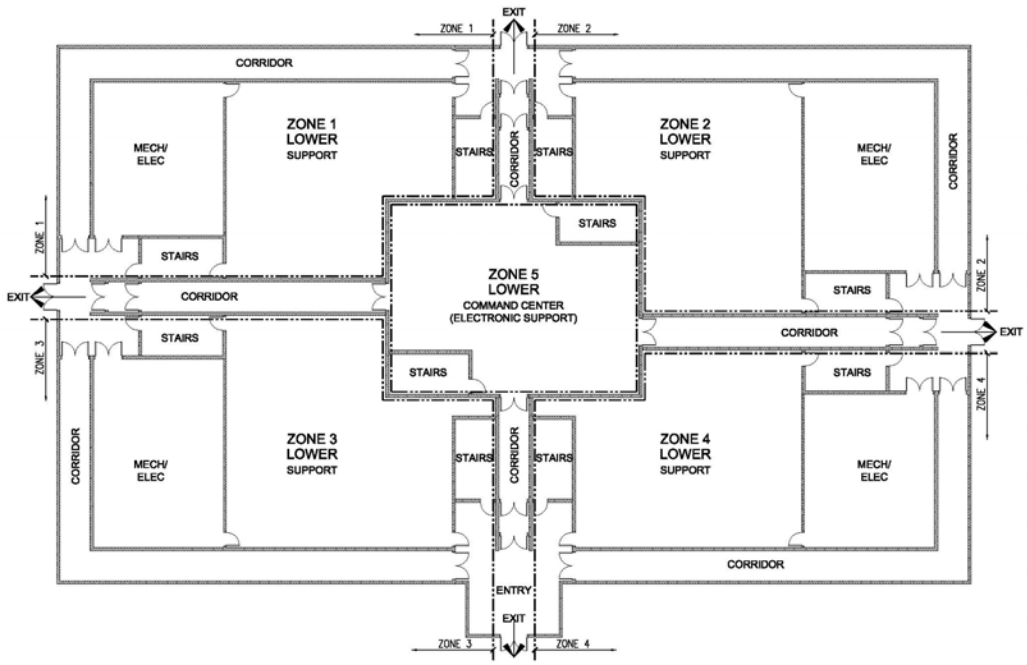

Figure 2-1. Example facility first floor plan

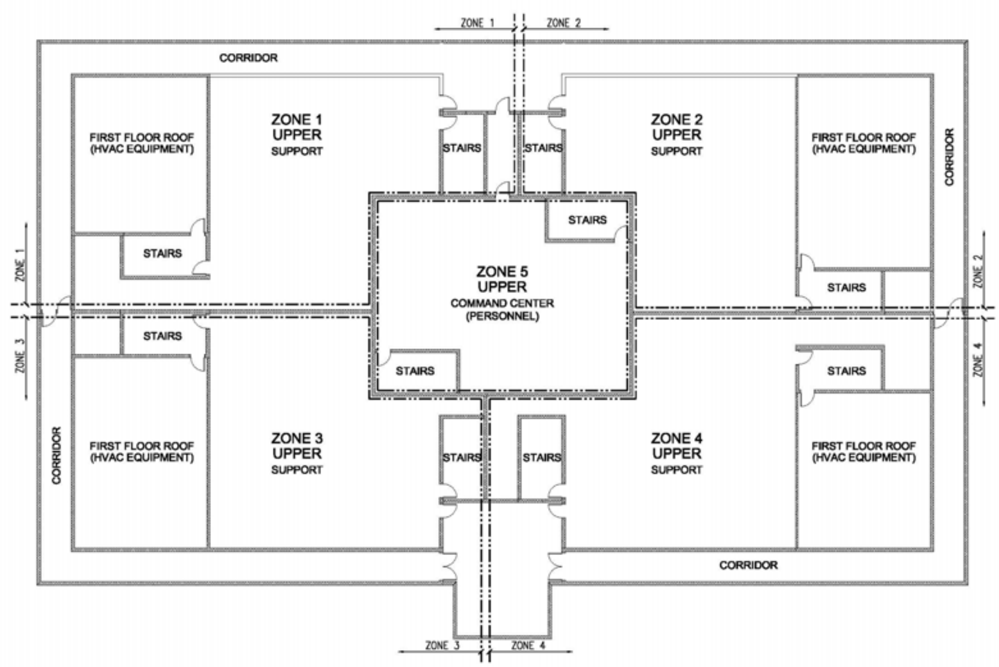

Figure 2-2. Example facility second floor plan

a. The example facility is a two-story structure of approximately 35,000 gross square feet (GSF) of floor plan, divided into five mission zones and containing four classes of secure space, as defined in table 2-1. The outer ring corridor provides a perimeter barrier for the internal space and a means of moving between zones without requiring penetration of internal barriers. This corridor also provides for accessibility and emergency egress as required by building codes. Public access to the building is through an entry checkpoint outside the perimeter of this corridor.

Table 2-1. Example facility space classification

Class	Area	Function	Security Level
0	Entry Checkpoint	Access and Screening	Low
1	Perimeter Corridor	Circulation and Egress	Medium
2	Zones 1 through 4	Mission Support	High
3	Zone 5 (Command Center)	Mission Critical	Highest

b. The peripheral zones (1 through 4) immediately inside the ring corridor contain less critical mission activities and support activities for Zone 5, which is a command center in this example. Each peripheral zone includes mechanical and electrical equipment space for utility service to that zone. Zone 5 represents the most critical space and receives a portion of its utility requirements from each of the peripheral zones.

2-6. Design criteria

The principles of LVD described in this TM are intended to supplement, not replace, existing guidelines for the design of utility systems for C4ISR facilities.

a. The primary references for general design criteria are:

(1) TM 5-601, Supervisory Control and Data Acquisition Systems for Command, Control, Communications, Computer, Intelligence, Surveillance, and Reconnaissance (C4ISR) Facilities.

(2) TM 5-691, Utility Systems Design Requirements for Command, Control, Communications, Computer, Intelligence, Surveillance, and Reconnaissance (C4ISR) Facilities.

(3) TM 5-692-2, Maintenance of Mechanical and Electrical Equipment at Command, Control, Communications, Computer, Intelligence, Surveillance, and Reconnaissance (C4ISR) Facilities – System Design Features.

(4) TM 5-698-1, Reliability/Availability of Electrical & Mechanical Systems for Command, Control, Communications, Computer, Intelligence, Surveillance, and Reconnaissance (C4ISR) Facilities.

b. The application of the LVD concept generates the following additional utility system design criteria and assumptions applicable to the example facility:

(1) Mission activities require the entire facility to be self-supporting in the absence of external utilities for a specified mission time. This may dictate substantial internal storage of fuel for boilers and generators and of water for plumbing systems and cooling system makeup. This requirement does not apply to utilities needed only for life safety functions, such as fire protection water.

(2) The mission-critical space (Zone 5) must be supplied by utilities from enough sources to meet the reliability criteria, with segregation of pathways adequate to ensure survival of the required capacity.

(3) The mission-critical space must have fast-acting automatic systems to isolate the connections to a peripheral zone when an event occurs. This will prevent introduction of an agent to the command center through ductwork, draining of the command center chilled water system through ruptured zone piping, and similar impacts.

(4) Activities in the mission support space (Zones 1 through 4) are duplicated, if necessary, by parallel activities in other zones and thus do not require redundant utility services.

(5) There is no need to maintain partial mission activity or survivability within a zone where an event occurs. Systems intended strictly to promote survival of personnel or limitation of damage within a zone are recommended but are considered to be in addition to and not part of the scope of the LVD concept.

2-7. Reliability criteria

In general, the utility systems serving each zone of a facility that incorporates the LVD concept should meet the target reliability, availability, and maintainability (RAM) criteria specified for the mission activity within that zone. RAM criteria and various modeling and analysis methodologies applicable to C4ISR facilities are described in detail in TM 5-698-1. As design proceeds, systems should be modeled and RAM analysis performed in accordance with TM 5-698-1 to verify that all criteria are met.

a. Regardless of the numerical RAM criteria applied, the minimum level of redundancy for utility services from the peripheral zones to the command center should be N+2, where N is the number of sources required to meet the load. This ensures that with one source out of service for maintenance, an event affecting another source will not result in interruption of service to the command center.

b. For the example facility, with four peripheral zones available to supply utilities to the command center, requiring that the command center be able to operate at full mission capacity from two of the four zones (N=2) while providing connections from all four produces an N+2 system. The N+2 mechanical and electrical utility systems described in subsequent chapters of this TM have been analyzed and shown to provide an availability of utilities to the command center of "six nines," or 99.9999 percent, generally considered acceptable for mission-critical spaces. The report of this analysis is provided in appendix C, Reliability Analysis of Example Systems.

2-8. Capacity criteria

The utility systems in each zone should be sized to meet the peak demand of that zone plus the portion of the command center load determined by applying the above reliability criteria to the number of sources. For the example facility, with N+2 redundancy, each zone system would be sized at 100 percent of the zone load plus 50 percent of the command center load as a minimum.

a. Limiting the complexity of the utility systems within the command center zone may dictate higher capacities in the zone sources than dictated by redundancy alone. For example, an electrical system within the command center that uses four 50 percent sources may require more complex switching and controls than one that uses four 100 percent sources. Plan for future growth when sizing equipment.

b. Appendix D, Example of Utility Capacity Calculation, demonstrates how the required capacity is developed for the systems in the example facility.

2-9. Vulnerabilities

The utility systems serving facilities that incorporate the LVD concept have the same vulnerabilities as those in traditional C4ISR facilities, consisting of internal failure and external threat. Internal failure is addressed through proper selection and sizing of equipment and components, selective coordination of protective devices, qualified operators, and an effective maintenance program. External threats are addressed in the traditional manner through hardening, perimeter security, redundancy of sources, and on-site generation.

a. One vulnerability unique to the LVD concept is the potential for common-mode internal failure of multiple sources where they are interconnected at the critical load. The example facility relies on the ability to serve the critical load from any of the four sources to meet the RAM criteria.

b. In order to meet this criteria the facility must have the ability to operate from multiple sources in parallel or to automatically transfer from one to another when a source fails. It should also have the ability to definitively isolate from failed source(s) to prevent the failure from expanding to involve otherwise healthy sources. Lastly, the facility should provide adequate physical segregation within transfer equipment to prevent an internal failure from affecting multiple sources.

2-10. Scalability

Scalability is a desirable design feature of facilities using the LVD concept. This is represented in the building layout of the example facility, in which zone demarcation barriers run vertically and connections for access and egress are limited to the perimeter corridor. The LVD concept can be applied to this type of building configuration with any number of peripheral zones as long as there are at least three utility sources available to meet the N+2 criteria for the most critical zone. Each zone is treated as a separate building from a structural and utility systems standpoint, allowing cost-effective configuration of a larger C4ISR facility using a modular approach of adding identical zones.

a. Caution is warranted in applying reliability criteria as the number of peripheral zones increases. The reliability and availability provided by an N+2 system configuration decreases as N increases because of the larger number of sources required to simultaneously function correctly to meet the load. In a facility designed with eight peripheral zones, an N+2 configuration requiring six sources to serve the command center load would result in a significant decrease in reliability from that provided by the four-zone N+2 configuration discussed above.

b. The systems required to automatically transfer load between sources and isolate failed sources also become more complex as the number of sources increases, resulting in a higher probability of failure within the command center. For these reasons, the number of utility sources required to meet the command center load (N) should be limited to two regardless of the number of peripheral zones in the facility.